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Taxonomy & Inventories

Research progress on nationally protected plants in the three most north-eastern provinces of China

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Abstract

Background

The three most north-eastern provinces of China (Heilongjiang, Jilin, and Liaoning) are rich in natural resources and have favourable geographical conditions, making them home to a large number of wild plant species. This paper summarises the distribution characteristics, endangerment degree and research status of nationally protected plants in these provinces based on online databases, literature review and field surveys.

New information

The results show that the north-eastern provinces have 31 families, 38 genera and 51 species of nationally protected plants. The endangered status includes both the endangered assessments made by China and those made globally. China has assessed 38 plant species as endangered, while 19 plant species are assessed as endangered globally. Currently, most of the protected plants have been studied, with in-situ and ex-situ conservation being the primary protective measures. In addition, this study also

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identified seven species of plants that are basically not covered by research and lack sufficient studies in the current literature and urgently need further in-depth investigation and long-term monitoring in order to improve the relevant conservation measures. This study provides a scientific basis for the conservation vacancies of plants under national key protection in the three north-eastern provinces, as well as a reference for formulating effective conservation policies and promoting further research.

Keywords

China, nationally protected plants, distribution characteristics, threatened status, research status

Introduction

China is one of the most biodiverse countries in the world, with unique ecosystems and rich species resources (State Council Information Office of the People's Republic of China 2021). Amongst them, the three most north-eastern provinces (Heilongjiang, Jilin and Liaoning) are rich in natural resources, not only possessing vast forest, wetland and grassland ecosystems, but also a large number of rare and endangered species, especially wild plants under national key protection (Fan et al. 2018). However, in recent years, the biodiversity of the three most north-eastern provinces is facing serious threats due to the intensification of human activities and changes in the natural environment (He 2020). Factors such as ecosystem degradation, habitat loss, climate change and invasion of exotic species have led to the deterioration of the living environment of many nationally key protected plants and a sharp decline in their populations (Ministry of Ecology an Environment of the People's Republic of China 2024).

According to the priorities in the Kunming-Montreal Global Biodiversity Framework (2022), which proposes key targets to conserve ecosystems, to reduce habitat loss and to prevent species extinction (United Nations Environment Programme (UNEP) and Convention on Biological Diversity (CBD) 2023), the three most north-eastern provinces are working to implement these targets, especially in flora conservation and restoration (Cao et al. 2022). Strengthening in-situ conservation and restoration of endangered plants, responding to climate change and enhancing habitat conservation (Yang et al. 2019) are all key initiatives in the three most north-eastern provinces in response to the Global Biodiversity Conservation Strategy (Ministry of Ecology an Environment of the People's Republic of China 2024). These initiatives not only help to improve the local biodiversity conservation environment, but also help to provide a model and experience for global biodiversity conservation.

In 1999, the State Forestry and Grassland Administration and the Ministry of Agriculture and Rural Development jointly released the first edition of the List of Wild Plants under State Key Protection (Ministry of National Forestry and Ministry of State for Agriculture 1999) and the situation of wild plant protection in China has changed greatly, with some

endangered wild plants being effectively protected (State Forestry and Grassland Administration 2021). However, some wild plants have become more endangered due to habitat destruction and over-utilisation (State Forestry and Grassland Administration 2021). Therefore, with the approval of the State Council, the State Forestry and Grassland Administration and the Ministry of Agriculture and Rural Development of the People's Republic of China, the latest version of the List of Wild Plants under State Key Protection was released in 2021 to address biodiversity conservation in the current situation (National Forestry and Grassland Administration 2021).

Flora research in the three most north-eastern provinces began in the mid-19th and 20th centuries, with Russian and Japanese scholars becoming the main research force (Cao et al. 2022). Early studies focused on basic investigations of plant classification and composition of the flora, such as the compilation of the Northeastern Plant Search List (Fu 1995). With the development of floristics, the focus of research gradually shifted to the origin and evolution of flora and its relationship with the environment, for example, the detailed analyses of Cao Wei et al. (Cao and Li 2008) of the vertical distribution pattern of the flora in the Changbai Mountains revealed the process of flora's adaptation and evolution in response to environmental changes. In recent years, flora research in the three most north-eastern provinces has made remarkable progress in terms of methodology and technology and the application of new technologies, such as molecular biology, remote sensing technology and geographic information systems (GIS), has provided strong support for in-depth studies of flora (Wang 2023).

There are many rare and endangered plants under national key protection in the three most north-eastern provinces, especially *Taxus cuspidata*, *Thuja koraiensis* and Orchidaceae. *Taxus cuspidata* is a national-level protected plant and a very small population of wild plants, mainly distributed in the north-eastern region of China (Institute of Botany, Chinese Academy of Sciences 2013), which has become an endangered species because of its narrow distribution area, serious habitat fragmentation and decreasing natural distribution (Liu 2024). *Taxus cuspidata* has become an endangered species. At present, the protection of *Taxus cuspidata* counters is mainly based on in-situ protection, supplemented by field return and relocation protection (Zhu et al. 2023). *Thuja koraiensis*, is only distributed in China in the Changbai Mountain area of Jilin Province, with low seed viability, coupled with over-exploitation, the geographical distribution of natural populations has greatly reduced and the natural regeneration capacity is very weak (Jin et al. 2019) and a nature reserve for *Thuja koraiensis* has been set up in the Changbai Mountain area (Yin et al. 2019). Orchidaceae is the family with the largest number of threatened species amongst angiosperms and also the family with the largest number of extinct species (Qin et al. 2017) and, due to the destruction of habitats, the existing Orchidaceae resources in northeast China have gradually decreased and, at present, Orchidaceae plants in northeast China are mainly zoned for protection in the habitats where they are located (Xu 2024).

In this paper, 51 species of plants under state key protection in the three most north-eastern provinces of China were studied and the list of plants under state key protection in the three most north-eastern provinces was compiled, along with their distribution,

threat level, threat factors and research status through literature, online database and field survey. This study aims to account for the distribution pattern of plants under state key protection in the three most north-eastern provinces, assess the endangered status of plants under state key protection in the three most north-eastern provinces and point out the research vacancies of plants under state key protection in the three most north-eastern provinces. The results of this study provide a scientific basis for the conservation vacancies of national key protected plants in the three most north-eastern provinces and, at the same time, the study provides a reference for the formulation of an effective conservation policy, which helps to promote further research on national key protected plants in the three most north-eastern provinces.

Materials and methods

Data sources

The main sources of data on the list and distribution of nationally protected plants in the three most north-eastern provinces include the "National Key Protected Wild Plants List (2021)" (National Forestry and Grassland Administration 2021), "The List of Wild Vascular Plants in Heilongjiang Province" (Wang et al. 2022), "The List of National Key Protected Wild Plants in Jilin Province (2021)" (Jilin Provincial Forestry and Grassland Administration 2021), "Catalogue of Higher Plant Diversity in Liaoning Province" (Zhang et al. 2022), the "Jilin Forestry and Grassland Bureau's wild plant column" (Jilin Provincial Forestry and Grassland Administration 2023) and relevant literature on 51 protected plants. The information derived from these references were compiled to create an overall list for these three provinces as a base for further investigations.

The protection levels of national protected plants in the three most north-eastern provinces are based on Article 2 of the "Wild Plant Protection Regulations of the People's Republic of China", (National Forestry and Grassland Administration 2017) which states: "The wild plants protected by these regulations refer to rare plants that grow naturally in their native habitat, as well as endangered and rare plants that grow naturally in their native habitat and have significant economic, scientific research or cultural value".

Level I protected plants are those that are critically endangered, with extremely limited populations, narrow distribution and strict environmental requirements for survival. The protection of these plants is crucial, as failure to protect them could lead to their extinction. Typically, Level I protected plants are characterised by the following features:

1. Extremely small populations;
2. Very narrow distribution range;
3. Extremely high ecological, economic or cultural value;
4. Facing significant human activity threats.

Level II protected plants are those that, while facing some threats, have relatively stable populations and distribution and are not yet at immediate risk of extinction. These plants still require protection to some degree, but the protection measures can be somewhat

more lenient compared to Level I protected plants. Level II protected plants are characterised by the following features:

1. Relatively stable populations;
2. Broader distribution range;
3. High ecological, economic or cultural value;
4. Threats are less severe compared to Level I protected plants.

The global endangered status of the national protected plants in the three most north-eastern provinces is determined according to the IUCN Red List Categories and Criteria (IUCN Species Survival Commission 2000). The endangered status categories include: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE).

The endangered status of the national protected plants in the three most north-eastern provinces of China is determined according to the "China Red List of Biodiversity - Higher Plants Volume" assessment report (Ministry of Ecology and Environment of People's Republic of China and Chinese Academy of Sciences 2013). The species' endangered status categories include: Extinct (EX), Extinct in the Wild (EW), Region Extinct (RE), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD).

The current research status of national protected plants in the three most north-eastern provinces is based on the Chinese and Latin names of 51 species of nationally protected plants distributed in the region as keywords. Literature searches were conducted in CNKI (China National Knowledge Infrastructure) and Web of Science. The search criteria were based on the research areas of the three north-eastern provinces, the north-eastern region, Heilongjiang Province, Jilin Province and Liaoning Province. The retrieved literature was then screened accordingly. The number of relevant publications and the related research fields for each species were determined.

Data processing

The main steps for processing data include:

1. Unify the Latin names in the following references: "List of National Key Protected Wild Plants (2021)" (National Forestry and Grassland Administration 2021), "Checklist of Wild Vascular Plants in Heilongjiang Province" (Wang et al. 2022), "List of National Key Protected Wild Plants in Jilin Province (2021)" (Jilin Provincial Forestry and Grassland Administration 2021) and "Catalog of Vascular Plant Diversity in Liaoning Province" (Zhang et al. 2022).

2. Match the plant lists of Heilongjiang Province and Liaoning Province with the "List of National Key Protected Wild Plants (2021)" (National Forestry and Grassland Administration 2021) and compile the "List of National Key Protected Wild Plants in

Heilongjiang Province" (Wang et al. 2022) and the "List of National Key Protected Wild Plants in Liaoning Province" (Zhang et al. 2022).

3. Based on the Wild Plant Column of the Jilin Provincial Forestry and Grassland Bureau Jilin Provincial Forestry and Grassland Administration 2023 (Jilin Provincial Forestry and Grassland Administration 2023) and relevant literature on 51 protected plant species, the distribution of the 51 protected plant species was compiled.

Checklist of national key protected wild plants in the three most north-eastern provinces of China

Family Actinidiaceae

Actinidia arguta (Siebold & Zucc.) Planch. ex Miq.

Distribution: Heilongjiang Province: Acheng District, Harbin City, Shangzhi City (Wang et al. 2022).

Jilin Province: Linjiang City, Helong City, Antu County, Fusong County, Wangqing County, Hunchun City, Jiaohe City, Ji'an City (Xiao et al. 2010, Li et al. 2015, Liu 2019b, Peng 2019).

Liaoning Province: Xifeng City, Qingyuan City, Huanren County, Fengcheng City, Benxi City, Xiuyan County, Zhuanghe City, Wafangdian District, Jinzhou District, Suizhong County (Liu and Zhu 2010, Zou 2017, Chang et al. 2020).

Notes: National Protected Plants (Level II).

(Fig. 1)

Figure 1. doi

Actinidia arguta.

Family Alismataceae

Sagittaria natans Pall.

Distribution: Heilongjiang Province: Acheng District, Daxing'anling Prefecture, Harbin City, Jixi City, Shangzhi City, Yichun City, Zhaodong City, Zhaozhou County, Beian City, Heihe City, Huma County, Hulun City, Jiayin County, Mohe City (Wang et al. 2022).

Jilin Province: Dunhua City, Dehui City, Fuyu City (Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Beipiao City, Shenyang City (field investigation) .

Notes: National Protected Plants (Level II).

Family Apiaceae

Carlesia sinensis Dunn

Distribution: Jilin Province: Antu County, Changbai Mountain Nature Reserve (Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Jianchang County, Chaoyang City, Fengcheng City, Dandong City, Donggang City, Anshan City, Jinzhou District, Zhuanghe City (Li et al. 2017).

Notes: National Protected Plants (Level II).

Glehnia littoralis F. Schmidt ex Miq.

Distribution: Liaoning Province: Linghai City, Huludao City, Xingcheng City, Suizhong County, Gaizhou City, Wafangdian District, Pulandian District, Jinzhou District, Changhai County (Li 2019).

Notes: National Protected Plants (Level II).

Family Araliaceae

Panax ginseng C. A. Mey.

Distribution: Heilongjiang Province: Shuangyashan City, Raohe County (Wang et al. 2022).

Jilin Province: Fusong County, Dunhua City, Jingyu County (Sun 2007, Liu 2014).

Liaoning Province: Tieling City, Qingyuan City, Xinbin County, Benxi City, Huanren County, Kuandian County, Fengcheng City, Anshan City, Yingkou City, Gaizhou City, Zhuanghe City (Wu 2012, Wang 2013, Liu 2019a).

Notes: National Protected Plants (Level II).

Family Aspleniaceae

Asplenium komarovii Akasawa

Distribution: Jilin Province: Baishan City, Changbai Korean Autonomous County, Fusong County, Linjiang City, Ji'an City (Jia et al. 2023).

Notes: National Protected Plants (Level II).

Family Cabombaceae

Brasenia schreberi J. F. Gmel.

Conservation status: LC

Distribution: Heilongjiang Province: Yichun City (Yu 1991).

Notes: National Protected Plants (Level II).

Family Crassulaceae

Rhodiola angusta Nakai

Distribution: Heilongjiang Province: Harbin City, Shangzhi City (Wang et al. 2022).

Jilin Province: Antu County, Fusong County, Changbai Mountain Nature Reserve (Jia 2022).

Notes: National Protected Plants (Level II).

Rhodiola rosea L.

Distribution: Heilongjiang Province: Mudanjiang City (Wang et al. 2022).

Jilin Province: Antu County, Fusong County, Changbai Korean Autonomous County, Changbai Mountain Nature Reserve (Jilin Provincial Forestry and Grassland Administration 2023).

Notes: National Protected Plants (Level II).

Rhodiola sachalinensis Boriss.

Distribution: Heilongjiang Province: Harbin City, Mudanjiang City, Qiqihar City, Hailin, Ning'an City, Shangzhi City (Wang et al. 2022).

Jilin Province: Antu County, Fusong County, Changbai Korean Autonomous County, Linjiang City, Dunhua City, Changbai Mountain Nature Reserve (Sheng et al. 2004, Jilin Provincial Forestry and Grassland Administration 2023).

Notes: National Protected Plants (Level II).

Family Cupressaceae

Thuja koraiensis Nakai

Conservation status: VN

Distribution: Jilin Province: Antu County, Tonghua City, Baishan City, Yanbian Area, Changbai Mountain Nature Reserve (Lan et al. 2021, Jilin Provincial Forestry and Grassland Administration 2023).

Notes: National Protected Plants (Level II).

Family Droseraceae

Aldrovanda vesiculosa L.

Conservation status: EN

Distribution: Heilongjiang Province: Qiqihar City, Tongjiang, Fuyuan (Shan et al. 2020, Wang et al. 2022).

Notes: National Protected Plants (Level I).

Family Ericaceae

Rhododendron dauricum L.

Distribution: Heilongjiang Province: Acheng District, Daxing'anling Area, Hailin City, Hegang City, Linkou County, Mohe City, Mudanjiang City, Qiqihar City, Shuangyashan City, Tahe County, Harbin City, Heihe City, Huma County, Hulin City, Jidong County, Jixi City, Jixian County, Jiayin County, Luobei County, Mishan City, Nenjiang City, Raohe County, Shangzhi City, Suifenhe City, Wuchang City, Yichun City (Wang et al. 2022).

Jilin Province: Linjiang City, Helong City, Antu County, Fusong County, Wangqing County, Hunchun City, Jiaohe City, Ji'an City, Yongji County, Huadian County, Jingyu City, Changbai Korean Autonomous County, Yanji City, Longjing City, Antu County, Changbai Mountain Nature Reserve (Man 2016, Du et al. 2019, Wu et al. 2023).

Liaoning Province: Beipiao City, Huanren County (Man 2016).

Notes: National Protected Plants (Level II).

Family Fabaceae

Glycine soja Siebold & Zucc.

Distribution: Heilongjiang Province: Counties of Heilongjiang Province (Liu 2004, Wei et al. 2011).

Jilin Province: Counties of Jilin Province (Liu 2004, Wei et al. 2011).

Liaoning Province: Counties of Liaoning Province (Liu 2004, Wei et al. 2011).

Notes: National Protected Plants (Level II).

(Fig. 2)

Figure 2. doi

Glycine soja.

Glycyrrhiza uralensis Fisch.

Distribution: Heilongjiang Province: Daqing City, Lindian County, Qiqihar City, Saertu District, Suihua City, Tailai County, Zhaoyuan County, Anda City, Duerbote

Mongol Autonomous County, Zhaodong City, Zhaozhou County (Zhao et al. 2004, You et al. 2022, Wang et al. 2022).

Jilin Province: Qian'an County, Nong'an County, Qianguo'erluosi Mongolian Autonomous County, Da'an City, Fuyu City, Taonan City, Tongyu County, Zhenlai County, Changling County, Baicheng City, Songyuan City, Siping City, Yanbian Korean Autonomous Prefecture (Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Jianping County, Beipiao City, Fuxin City, Heishan County, Zhangwu County, Kangping County (field investigation).

Notes: National Protected Plants (Level II).

Family Fucaceae

Silvetia siliquosa

Distribution: Liaoning Province: Liaoning coastal area, Changhai County, Jin County (Jinzhou District), Dalian City, Lushunkou District, Fu County (Wafangdian City) (Zeng and Zhang 1958).

Notes: National Protected Plants (Level II).

Family Haloragaceae

Myriophyllum ussuriense (Regel) Maxim.

Conservation status: LC

Distribution: Heilongjiang Province: Heihe City, Qiqihar City, Luobei County, Hulin County, Mishan County, Raohe County, Jidong County, Nenjiang County, Nenjiang County, Boli County, Linkou County, Longjiang County, Fujin County, Huinan County, Fuyuan (Wang et al. 2022).

Jilin Province: Dunhua City, Helong City, Longjing City, Antu County (Jilin Provincial Forestry and Grassland Administration 2023).

Notes: National Protected Plants (Level II).

Family Hydrocharitaceae

Ottelia alismoides (L.) Pers.

Conservation status: LC

Distribution: Heilongjiang Province: Hulin City, Jixi City, Qiqihar City, Mishan City (Wang et al. 2022).

Notes: National Protected Plants (Level II).

Family Liliaceae

Fritillaria maximowiczii Freyn

Distribution: Heilongjiang Province: Acheng District, Daxing'anling Prefecture, Qiqihar City, Yichun City, Huma County, Xunke County (Wang et al. 2022).

Jilin Province: Huinan County, Jingyu City, Fusong County, Changbai Korean Autonomous County, Liuhe County, Tonghua City, Jiaohe City, Dunhua City, Antu County (Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Suizhong County, Jianchang County, Chaoyang City, Lingyuan City (field investigation).

Notes: National Protected Plants (Level II).

(Fig. 3)

Figure 3. doi

Fritillaria maximowiczii.

Fritillaria usuriensis Maxim.

Distribution: Heilongjiang Province: Baoqing County, Harbin City, Heihe City, Hulin City, Mishan City, Ning'an City, Qiqihar City, Wuchang City, Yilan County, Shangzhi City, Yichun City (Wang et al. 2022).

Jilin Province: Dongchang District, Linjiang City, Jiutai District, Erdao District, Erdaojiang District, Nong'an County, Nanguan District, Shuangyang District, Antu County, Kuancheng District, Dehui City, Fusong County, Chaoyang District, Liuhe County, Huadian City, Meihekou City, Yushu City, Wangqing County, Lvyuan District, Shulan City, Jiaohe City, Huinan County, Tonghua County, Ji'an City (Li 2010, Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Dandong City, Kuandian County, Fengcheng City, Benxi City, Huanren County, Qingyuan City, Xinbin County, Fushun City, Shenyang City (Li 2010).

Notes: National Protected Plants (Level II).

Lilium amabile Palib.

Distribution: Liaoning Province: Dandong City, Fengcheng City, Donggang City, Shenyang City (Xu and Lei 2010, Cui 2023).

Notes: National Protected Plants (Level II).

Family Lycopodiaceae

Huperzia asiatica (Ching) N. Shrestha & X. C. Zhang

Distribution: Heilongjiang Province: Harbin City, Ning'an City, Qiqihar City, Yichun City (Wang et al. 2022).

Jilin Province: Antu County, Wangqing County, Dunhua City, Changbai Mountain Nature Reserve (Jilin Provincial Forestry and Grassland Administration 2023).

Notes: National Protected Plants (Level II).

Huperzia miyoshiana (Makino) Ching

Distribution: Heilongjiang Province: Harbin City, Ning'an City, Qiqihar City, Yichun City (Wang et al. 2022).

Jilin Province: Linjiang City, Antu County, Fusong County, Changbai Korean Autonomous County, Jingyu County (Zhang and Kong 1998, Chinese Virtual Herbarium 2025, National Specimen Information Infrastructure 2025).

Liaoning Province: Kuandian County, Zhuanghe City (Chinese Virtual Herbarium 2025).

Notes: National Protected Plants (Level II).

Huperzia selago (L.) Bernh. ex Schrank & Mart.

Distribution: Heilongjiang Province: Qitaihe City, Qiqihar City, Yichun City (Wang et al. 2022).

Jilin Province: Antu County, Fusong County, Changbai Korean Autonomous County, Jingyu County, Helong City (Zhang and Kong 1998).

Notes: National Protected Plants (Level II).

Huperzia serrata (Thunb. ex Murray) Trevis.

Distribution: Heilongjiang Province: Dongning City, Hailin City, Shuangyashan City, Raohe County, Shangzhi City, Tahe County, Yichun City (Wang et al. 2011, Wang et al. 2022).

Jilin Province: Línjiāng City, Antu County, Fusong County, Dunhua City, Changbai Korean Autonomous County, Ji'an City, Jingyu County (Wang et al. 2011).

Liaoning Province: Benxi County, Kuandian County, Huanren County, Fengcheng City, Xinbin County (Wang et al. 2011).

Notes: National Protected Plants (Level II).

Family Lythraceae

Trapa incisa Siebold & Zucc.

Conservation status: LC

Distribution: Heilongjiang Province: Harbin City, Qiqihar City, Shangzhi City (Wang et al. 2022).

Jilin Province: Fuyu City, Dehui City, Dunhua City, Hunchun City (Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Kaiyuan County, Pulandian District (Lang and Zhang 1979).

Notes: National Protected Plants (Level II).

Family Malvaceae

Tilia amurensis Rupr.

Conservation status: LC

Distribution: Heilongjiang Province: Acheng District, Binxian, Daqing City, Hulan District, Jidong County, Jixi City, Mudanjiang City, Mulan County, Nenjiang City, Qitaihe City, Qiqihar City, Shuangyashan City, Suihua City, Tonghe County, Anda City, Baoqing County, Bobo County, Harbin City, Heihe City, Luobei County, Mishan City, Ning'an City, Shangzhi City, Sunwu County, Yichun City (Zhou 2008, Wang et al. 2022).

Jilin Province: Dongchang District, Linjiang City, Erdaojiang District, Helong City, Antu County, Fusong County, Dunhua City, Liuhe County, Meihekou City, Wangqing County, Hunchun City, Jiaohe City, Huinan County, Tonghua County, Changbai Korean Autonomous County, Ji'an City, Jingyu County (Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Xianrendong National Nature Reserve, Fengcheng City, Baishilazi National Nature Reserve, Xiuyan County, Kuandian County, Bailangshan National Nature Reserve, Fushun County, Xinbin County, Benxi County, Huanren County, Qingyuan County, Kaiyuan City, Tieling County, Xifeng County, Binglashan National Forest Park in various regions of Liaoning (field investigation) (Zhou 2008).

Notes: National Protected Plants (Level II).

Family Nymphaeaceae

Nelumbo nucifera Gaertn.

Distribution: Heilongjiang Province: Sanjiang Plain, Songnen Plain, Fangzheng, Mulan County, Ning'an City, Wuchang City (Xue et al. 2005, Xue et al. 2015).

Jilin Province: Jingxin Town, Hunchun (Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Huanren County, Jinzhou District, Pulandian District, Haicheng City, Liaoyang County, Liaozhong District, Xinmin City, Tai'an County, Suizhong County, Zhangwu County (field investigation) (Fu 2021, Plant photo bank of China 2025).

Notes: National Protected Plants (Level II).

(Fig. 4)

Figure 4. doi

Nelumbo nucifera.

Family Oleaceae

Fraxinus mandshurica Rupr.

Conservation status: LC

Distribution: Heilongjiang Province: Acheng District, Hegang City, Hulin City, Jixi City, Mishan City, Mudanjiang City, Qiqihar City, Harbin City, Yichun City (Zhao 2021, Wang et al. 2022, Liang et al. 2023).

Jilin Province: Dongchang District, Linjiang City, Erdaojiang District, Helong City, Antu County, Yanji City, Fusong County, Dunhua City, Liuhe County, Huadian City, Meihekou City, Yongji County, Wangqing County, Hunchun City, Panshi City, Shulan City, Jiaohe City, Huinan County, Tonghua County, Changbai Korean Autonomous County, Ji'an City, Jingyu County (Zhao 2021, Liang et al. 2023).

Liaoning Province: Haicheng City, Wafangdian District, Pulandian District, Zhuanghe City, Anshan City, Nanpiao District, Xifeng City, Benxi County, Dengta City, Fengcheng City, Fushun County, Gaizhou City, Ganjingzi District, Heishan County, Huanren County, Kuandian County, Mingshan District, Pingshan District, Dongling District, Qingyuan County, Shiqiaozhuang Development Zone, Suizhong County, Xinbin County, Xiuyan County, Yixian County (Zhao 2021, Liang et al. 2023).

Notes: National Protected Plants (Level II).

Family Orchidaceae

Cypripedium calceolus L.

Conservation status: LC

Distribution: Heilongjiang Province: Harbin City, Huma County, Jiayin County, Shangzhi City, Yichun City, Jixi Hulin Zhenbao Island Nature Reserve, Nenjiang Central Station Nature Reserve (Wang et al. 2022, Wu 2022).

Jilin Province: Linjiang City, Helong City, Antu County, Fusong County, Hunchun City, Huadian, Dunhua, Wangqing, Longjing, Tumen (Zhao 2013, Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Benxi City, Huanren County, Qingyuan City, Xinbin County (field investigation) .

(Fig. 5)

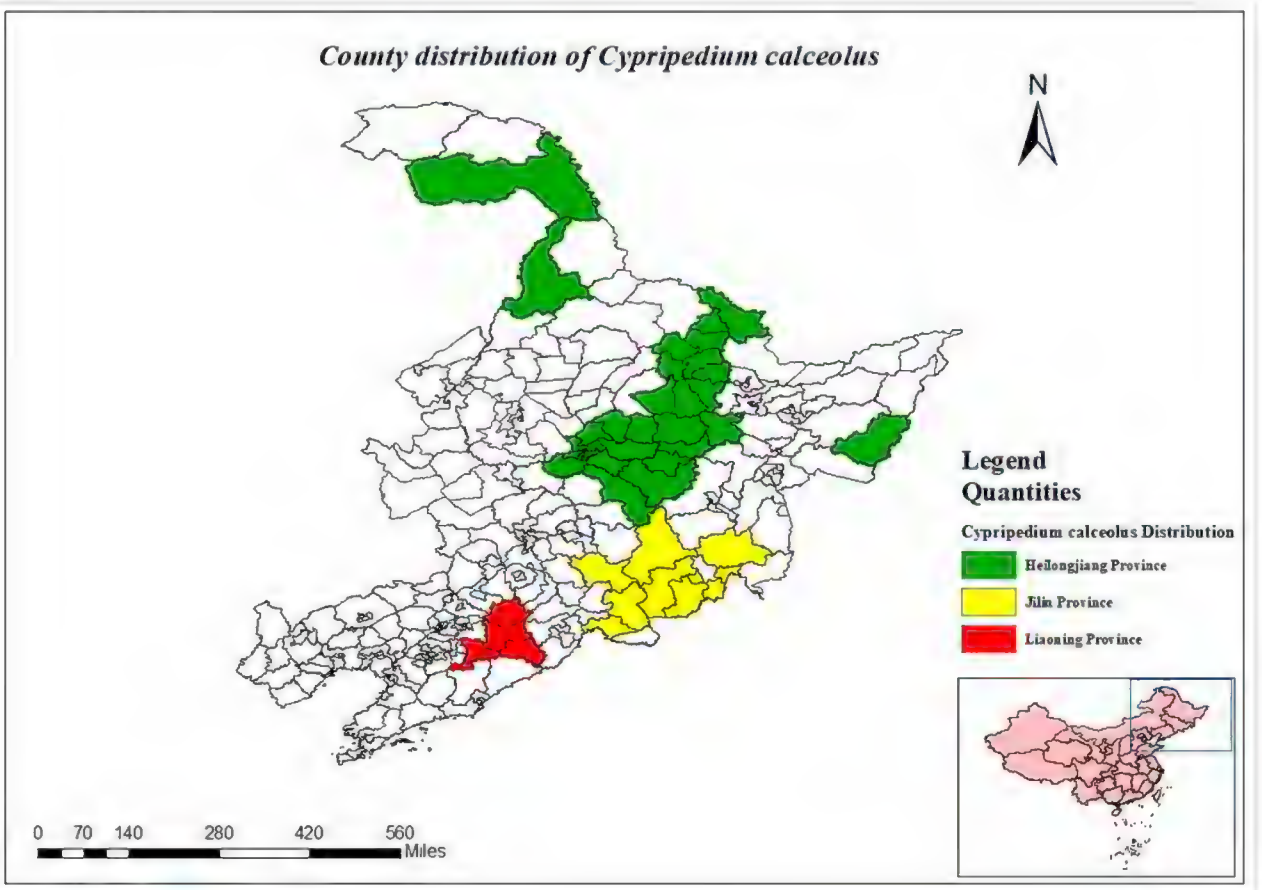

Figure 5. doi

County distribution of *Cypripedium calceolus*.

Notes: National Protected Plants (Level II).

(Fig. 6)

Figure 6. doi

Cypripedium calceolus.

Cypripedium guttatum Sw.

Conservation status: LC

Distribution: Heilongjiang Province: The Greater Khingan Range area, Harbin City, Hegang City, Hulin City, Jixi City, Qiqihar City, Tieli City, Heihe City, Huma County, Jiayin County, Shangzhi City, Yichun City, Raohe, Jiayin Maolan Gully, Heihe Shengshan Nature Reserve, Nenjiang Central Station Nature Reserve, Jiagedaqi Guli Forest Farm, Huzhong Nature Reserve (Li 2020, Wang et al. 2022, Wu 2022).

Jilin Province: Dongchang District, Linjiang City, Erdaojiang District, Helong City, Tumen City, Antu County, Yanji City, Fusong County, Dunhua City, Liuhe County, Meihekou City, Jiangyuan District, Wangqing County, Hunjiang District, Hunchun City, Huinan County, Tonghua County, Changbai Korean Autonomous County, Ji'an City, Jingyu County, Longjing City, Jiaohe, Yanbian, Changbai Mountain Nature Reserve (Zhao 2013, Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Benxi City, Huanren County, Fengcheng City (Li 2020).

(Fig. 7)

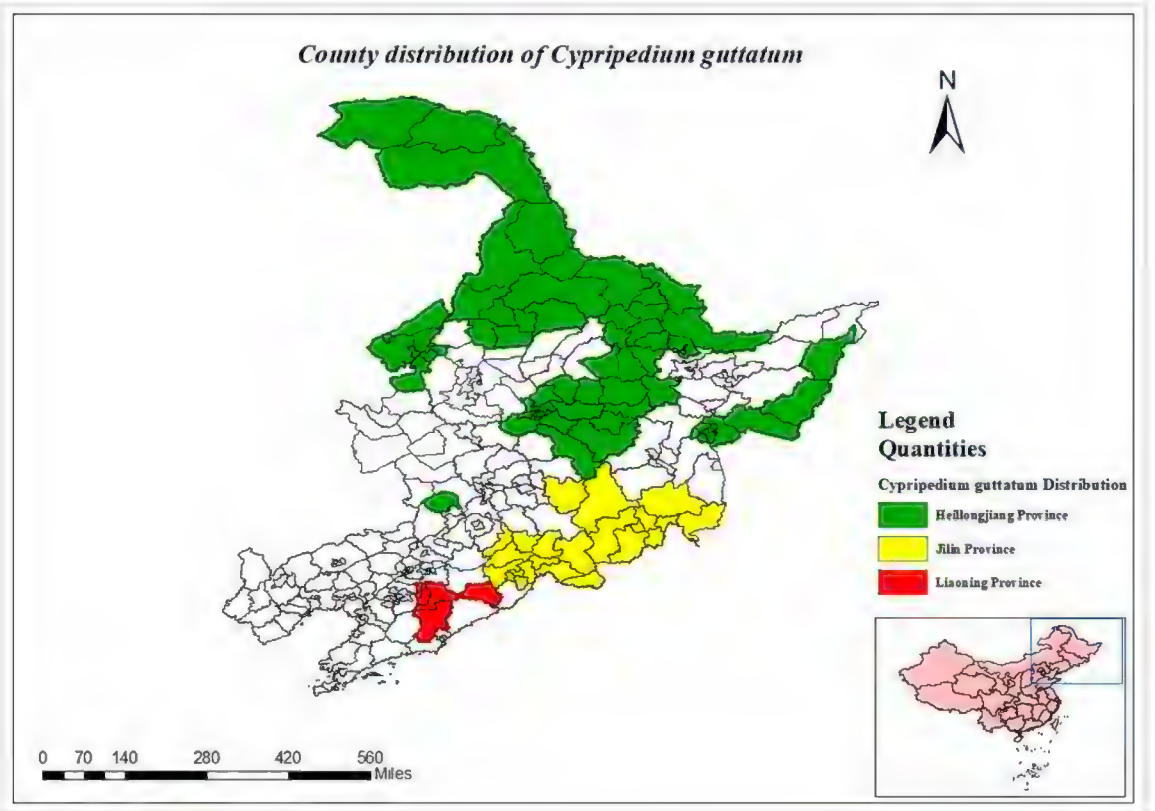

Figure 7. doi

County distribution of *Cypripedium guttatum*.

Notes: National Protected Plants (Level II).

(Fig. 8)

Figure 8. doi

Cypripedium guttatum.

Cypripedium macranthos Sw.

Conservation status: LC

Distribution: Heilongjiang Province: The Greater Khingan Range area, Harbin City, Hegang City, Heihe City, Huma County, Jixi City, Jiayin County, Luobei County, Mishan City, Ning'an City, Qiqihar City, Shangzhi City, Shuangyashan City, Yichun City, Raohe, Jixi Hulin Zhenbao Island Nature Reserve, Nenjiang Central Station Nature Reserve, Jiagedaqi Guli Forest Farm and Tahe (Li 2020, Wu 2022).

Jilin Province: Jiaohe City, Liuhe County, Jingyu City, Fusong County, Dunhua City, Wangqing County, Antu County, Yanji and Changbai Mountain Nature Reserve (Zhao 2013, Li 2020).

Liaoning Province: Xinbin County, Qingyuan City, Benxi City, Huanren County, Kuandian County, Dandong City, Fengcheng City, Kaiyuan City, Xifeng City (Li 2020).

(Fig. 9)

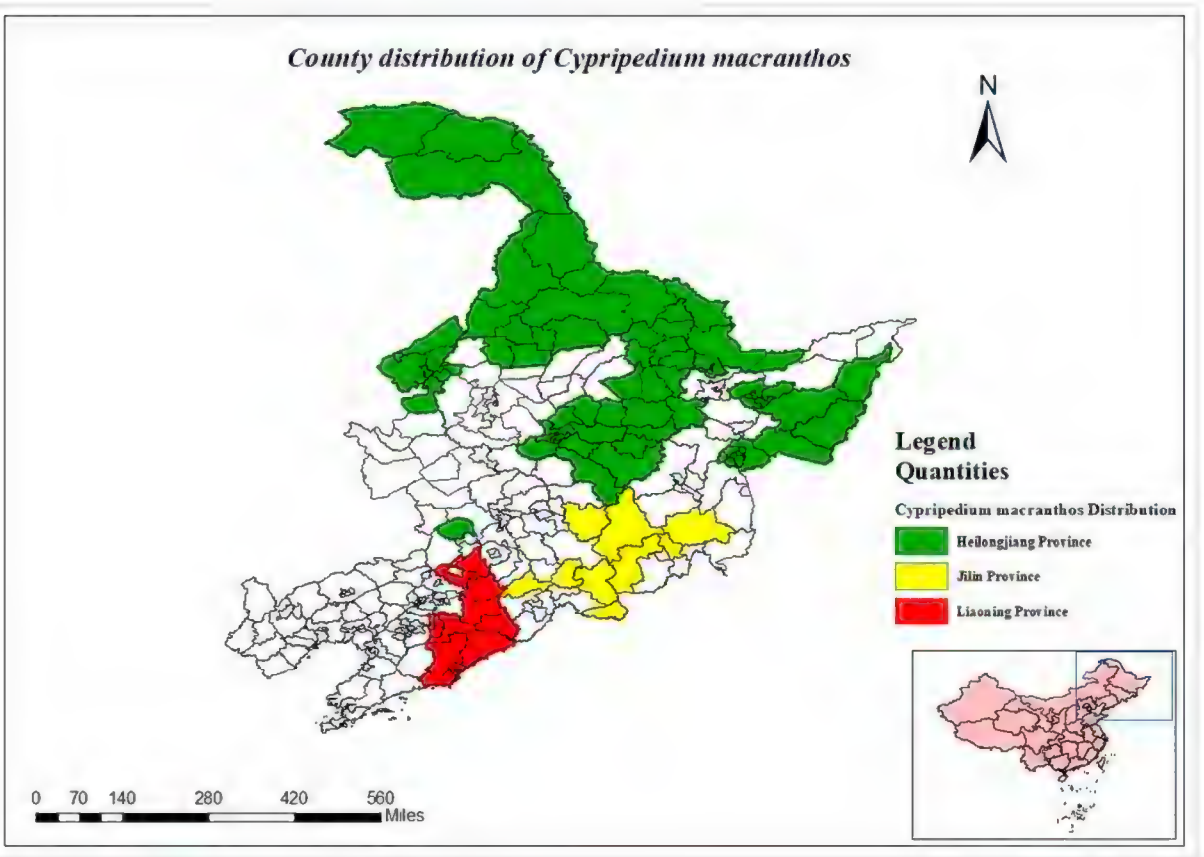

Figure 9. doi

County distribution of *Cypripedium macranthos*.

Notes: National Protected Plants (Level II).

(Fig. 10)

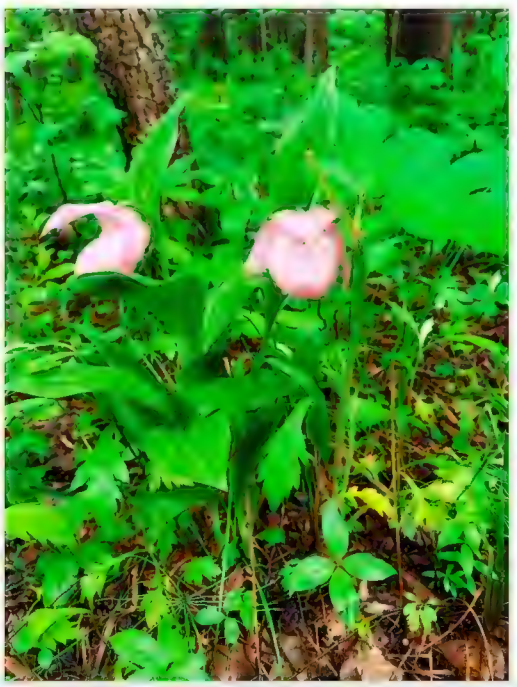

Figure 10. doi

Cypripedium macranthos.

Cypripedium shanxiense S. C. Chen

Conservation status: NT

Distribution: Heilongjiang Province: Ta River, Huzhong Nature Reserve, Yichun City (Wang et al. 2022).

Jilin Province: Baishan City, Tonghua City (Zhao 2013).

Liaoning Province: Huanren County (Li and Li 2020) .

(Fig. 11)

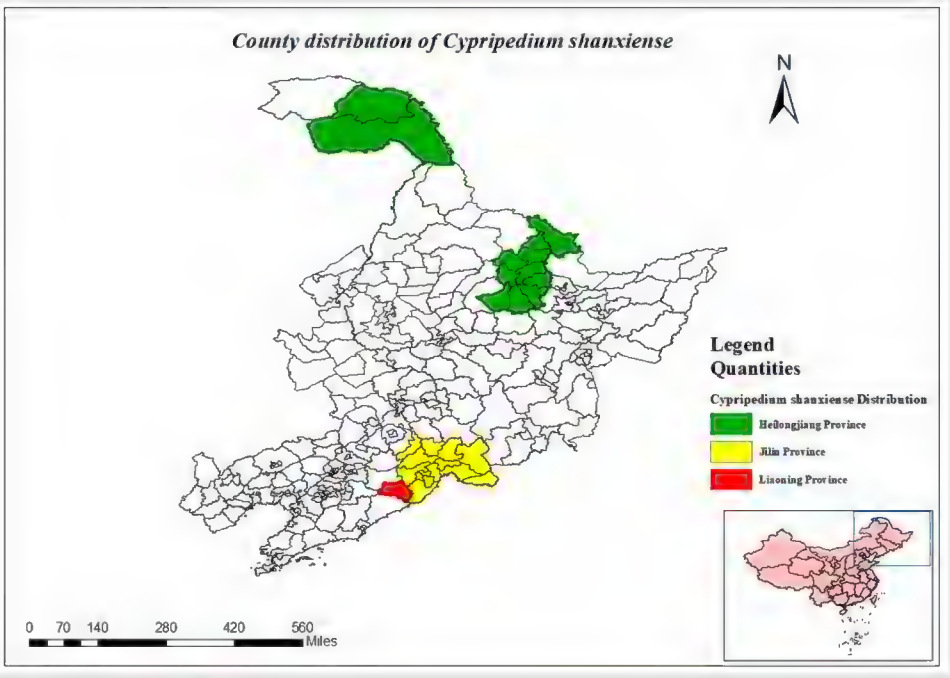

Figure 11. doi

County distribution of *Cypripedium shanxiense*.

Notes: National Protected Plants (Level II).

Cypripedium × ventricosum Sw.

Distribution: Heilongjiang Province: Yichun City, Jixi City, Jiamusi City (Wang et al. 2022, Wu 2022).

Jilin Province: Yanji City, Wangqing County, Jiaohe City, Hunchun City, Dunhua City, Longjing City, Antu County, Tumen City, Changbai Mountain Nature Reserve (Zhao 2013, Jilin Provincial Forestry and Grassland Administration 2023).

(Fig. 12)

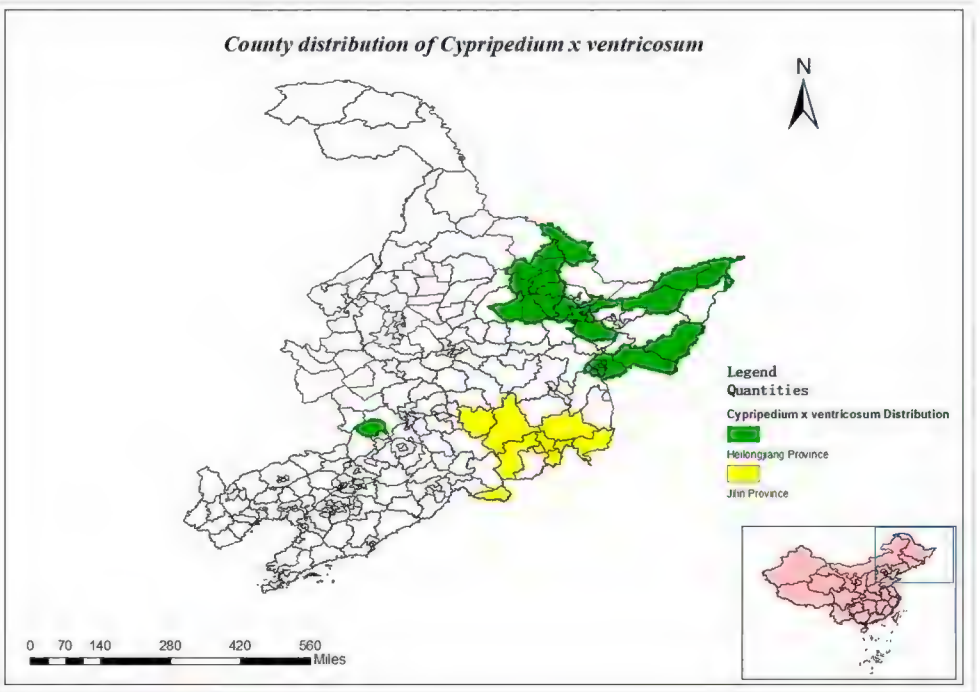

Figure 12. doi

County distribution of *Cypripedium x ventricosum*.

Notes: National Protected Plants (Level II).

Gastrodia elata Bl.

Conservation status: VN

Distribution: Heilongjiang Province: Xiaoxing'an Mountains, Laoyeling Mountains (Wang et al. 2022).

Jilin Province: Antu County (Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Benxi City, Xinbin County, Huanren County, Kuandian County, Zhuanghe City, Xiuyan County (Guan 2006).

Notes: National Protected Plants (Level II).

(Fig. 13)

Figure 13. doi

Gastrodia elata.

Gymnadenia conopsea (L.) R. Br.

Distribution: Heilongjiang Province: Huazhong, Xinlin District, Tahe Country, Jiagedaqi, Changbai Mountain, Huachuan County Xiaoshitou, Beian Weihuling, Qianshan, Xiaoxing'anling (Wang et al. 2022).

Jilin Province: Dongchang District, Linjiang City, Erdaojiang District, Antu County, Fusong County, Liuhe County, Huadian City, Meihekou City, Wangqing County, Hunchun City, Huinan County, Tonghua County, Changbai Korean Autonomous County, Ji'an City, Jingyu County, Jiaohe City, Dunhua City, Changbai Mountain Nature Reserve (Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Qingyuan City, Huanren County, Fengcheng City, Xifeng City (National Specimen Information Infrastructure 2025).

Notes: National Protected Plants (Level II).

Family Orobanchaceae

Boschniakia rossica (Cham. & Schltdl.) B. Fedtsch.

Distribution: Heilongjiang Province: Huma County, Daxing'anling area (Sun et al. 1995, An et al. 2011).

Jilin Province: Antu County, Fusong County, Changbai Korean Autonomous County (Sun et al. 1995, Yu et al. 1996).

Notes: National Protected Plants (Level II).

(Fig. 14)

Figure 14. doi

Boschniakia rossica.

Family Pinaceae

Pinus densiflora var. *ussuriensis* Liou & Z. Wang

Distribution: Heilongjiang Province: Jidong County, Mudanjiang City, Muling City, Jixi City, Mishan City (Chen and Sun 2012, Wang et al. 2022).

Notes: National Protected Plants (Level II).

Pinus koraiensis Siebold & Zucc.

Conservation status: LC

Distribution: Heilongjiang Province: Dongning City, Hailin City, Hegang City, Hulin City, Jidong County, Jixi City, Jiamusi City, Mishan City, Mudanjiang City, Ning'an City, Shangzhi City, Shuangyashan City, Suifenhe City, Suihua City, Tieli City, Xinlin District, Raohe County, Tangyuan County, Yichun City (Wu and Han 1990, Jia 2011, Song 2013, Dong 2018, Chen et al. 2021, Wang et al. 2022).

Jilin Province: Dongchang District, Linjiang City, Jiutai District, Erdaojiang District, Helong City, Antu County, Fusong County, Dunhua City, Liuhe County, Huadian City, Meihekou City, Wangqing County, Jiaohe City, Huinan County, Tonghua County,

Changbai Korean Autonomous County, Ji'an City, Jingyu County (Wang 2007, Jia 2011, Shang et al. 2013, Dong 2018, Abudureheman et al. 2023).

Liaoning Province: Benxi County, Huanren County, Fengcheng City, Kuandian County, Xinbin County (Guo et al. 1998, Yao 2019).

Notes: National Protected Plants (Level II).

Pinus sylvestris var. *sylvestriformis* (Taken.) W. C. Cheng & C. D. Chu

Distribution: Jilin Province: Dongchang District, Jiutai District, Erdaojiang District, Helong City, Antu County, Fusong County, Dunhua City, Liuhe County, Meihekou City, Wangqing County, Jiaohe City, Huinan County, Tonghua County, Changbai Korean Autonomous County, Ji'an City (Jilin Provincial Forestry and Grassland Administration 2023).

Notes: National Protected Plants (Level II).

Family Poaceae

Coleanthus subtilis (Tratt.) Seidel

Conservation status: LC

Distribution: Heilongjiang Province: Harbin City (Wang et al. 2022).

Notes: National Protected Plants (Level II).

Zoysia sinica Hance

Distribution: Liaoning Province: Dalian suburbs (Heishan County), Pulandian District (Chengzi Tan) (Wang 2003).

Notes: National Protected Plants (Level II).

Family Rosaceae

Malus komarovii (Sarg.) Rehder

Conservation status: EN

Distribution: Jilin Province: Antu County, Changbai Korean Autonomous County, Baishan City, Linjiang City, Changbai Mountain Nature Reserve (Jilin Provincial Forestry and Grassland Administration 2023).

Notes: National Protected Plants (Level II).

Rosa rugosa Thunb.

Distribution: Jilin Province: Hunchun Jingxin Town (Zhao 2008).

Liaoning Province: Jinzhou District, Changhai County, Lushunkou District, Zhuanghe City, Dalian City, Donggang City, Yingkou Bayuquan (Qin et al. 1994, Zhao 2008).

Notes: National Protected Plants (Level II).

(Fig. 15)

Figure 15. doi

Rosa rugosa.

Family Rutaceae

Phellodendron amurense Rupr.

Distribution: Heilongjiang Province: Bin County, Bobl County, Daqing Mountain County, Daxing'anling Area, Dongning City, Fujin City, Hegang City, Huma County, Hulin City, Huachuan County, Jixi City, Jiayin County, Linkou County, Luobei County, Mudanjiang City, Mulan County, Muling City, Ning'an City, Qiqihar City, Qing'an County, Raohe County, Shuangyashan City, Suiling County, Sunwu County, Tangyuan County, Tonghe County, Wuchang City, Xunke County, Yanshou County, Yilan County, Baoqing County, Harbin City, Heihe City, Jixian County, Mishan City, Nenjiang City, Shangzhi City, Yichun City (Yan et al. 2006, Zhang et al. 2012, Zhang et al. 2016, Wang et al. 2022).

Jilin Province: Dongchang District, Linjiang City, Jiutai District, Erdaojiang District, Helong City, Antu County, Yanji City, Fusong County, Dunhua City, Liuhe County, Huadian City, Meihekou City, Yongji County, Wangqing County, Hunchun City, Panshi

City, Shulan City, Jiaohe City, Huinan County, Tonghua County, Changbai Korean Autonomous County, Ji'an City, Jingyu County (Yan et al. 2006, Xian 2011, Yi et al. 2013, Zhang 2016).

Liaoning Province: Beizhen City, Benxi County, Dengta City, Fengcheng City, Fushun County, Gaizhou City, Haicheng City, Huanren County, Kaiyuan City, Kuandian County, Lianshan District, Liaoyang County, Mingshan District, Nanfen District, Qinghe District, Qingyuan County, Shuncheng District, Suizhong County, Tieling County, Xifeng County, Xinbin County, Xiuyan County, Zhen'an District (Yan et al. 2006, Zhang 2016, Gu 2018, Zhang 2019).

Notes: National Protected Plants (Level II).

(Fig. 16)

Figure 16. doi

Phellodendron amurense.

Family Scheuchzeriaceae

Scheuchzeria palustris L.

Conservation status: LC

Distribution: Heilongjiang Province: Suifenhe City, Hailin City, Ning'an City, Muling City, Dongning County, Linkou County, Jixi City, Hulin City, Mishan City, Jidong County, Shuangyashan City, Jixian County, Youyi County, Baoqing County, Raohe County (Wang et al. 2022).

Jilin Province: Linjiang City, Changbai and Changbai Mountain Nature Reserve (Jilin Provincial Forestry and Grassland Administration 2023, National Specimen Information Infrastructure 2025).

Notes: National Protected Plants (Level II).

Family Sphagnaceae

Sphagnum multifibrosum X. J. Li & M. Zang

Distribution: Heilongjiang Province: The Lesser Khingan Range (accessed at the Herbarium of the Shenyang Institute of Ecology).

Notes: National Protected Plants (Level II).

Sphagnum squarrosum Crome

Distribution: Heilongjiang Province: The forestry bureaus of Xiaoxing'anling such as Hongxing, Fenglin, Shuangzi River, Cuiluan, Dailing etc., the forestry bureaus of Daxing'anling such as Mo'erga, Genhe and A'ershan etc., the forest areas of Ning'an County including the Daha Lin and Jingpo Lake, as well as Yichun, Ningan, Huma County, Longjiang County and Hailin City (accessed at the Herbarium of the Shenyang Institute of Ecology).

Jilin Province: Jiaohe County, Antu County, Dunhua County, Fusong County, Linjiang County, Changbai County, Jingyu City, Changbai Mountain Nature Reserve (accessed at the Herbarium of the Shenyang Institute of Ecology).

Notes: National Protected Plants (Level II).

Family Taxaceae

Taxus cuspidata Siebold & Zucc.

Conservation status: LC

Distribution: Heilongjiang Province: Mudanjiang City, Muling City, Suileng County, Ning'an City (Wang et al. 2022).

Jilin Province: Linjiang City, Helong City, Antu County, Fusong County, Dunhua City, Wangqing County, Changbai Korean Autonomous County, Jingyu County (Jilin Provincial Forestry and Grassland Administration 2023).

Liaoning Province: Benxi County, Huanren County, Kuandian County (Liu 2007).

(Fig. 17)

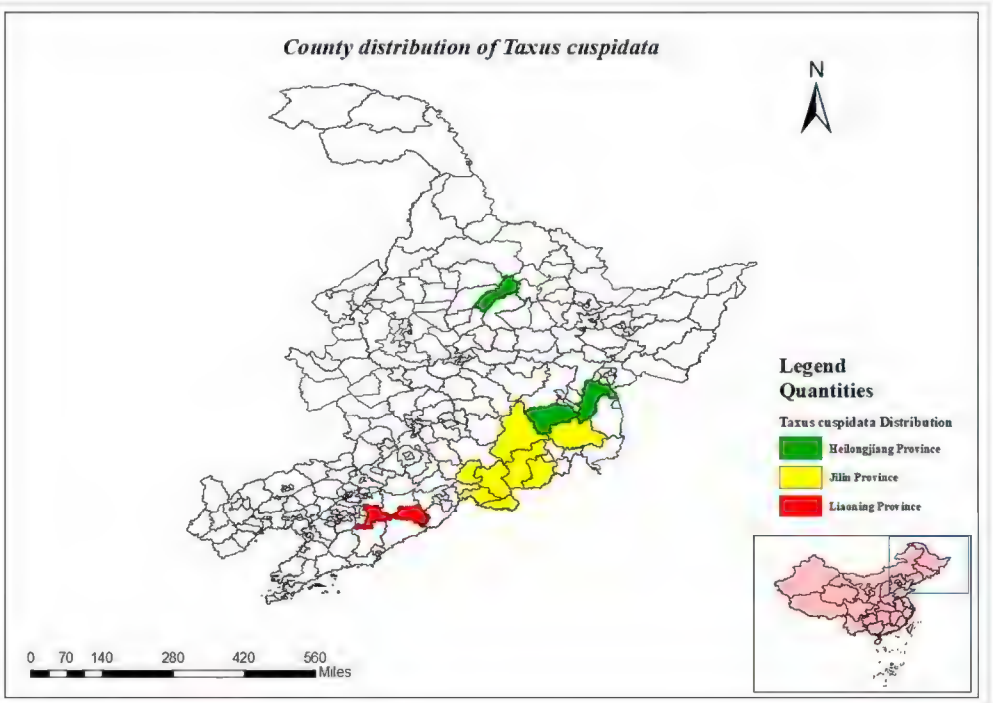

Figure 17. doi

County distribution of *Taxus cuspidata*.

Notes: National Protected Plants (Level I).

Family Tricholomataceae

Tricholoma matsutake (S. Ito & S. Imai) Singer

Distribution: Heilongjiang Province: Dongning City (Wang et al. 2022).

Jilin Province: Jilin City, Yanbian Korean Autonomous Prefecture, Tonghua County, Baishan City, the eight counties and cities of Yanbian Prefecture, Helong City, Longjing City, Wangqing County, Antu County (Xu 2021).

Liaoning Province: Kuandian County (field investigation).

Notes: National Protected Plants (Level II).

Family Typhaceae

Sparganium hyperboreum Laest. ex Beurl.

Conservation status: LC

Distribution: Heilongjiang Province: Harbin City, Yichun City, Muling Country, Mohe County (Wang et al. 2022).

Jilin Province: Heilong City, Antu County (Jilin Provincial Forestry and Grassland Administration 2023).

Notes: National Protected Plants (Level II).

Analysis

Distribution at the county level

The three most north-eastern provinces of China (Heilongjiang, Jilin and Liaoning) have a total of 34 prefecture-level cities, one region and one autonomous prefecture, along with 275 counties (cities, districts). In Jilin Province, the protected plant species in Antu County and Fusong County exceed 20 species. Amongst these, Antu County has the highest number of protected plant species, with 30 species, followed by Fusong County, which has 27 species. In total, 30 counties (cities, districts) have between 16 to 20 species of nationally protected plants, accounting for 10.91% of the total counties (cities, districts). Of these, 27 are located in Heilongjiang Province, two in Jilin Province and one in Liaoning Province. There are 32 counties (cities, districts) with 11 to 15 species of nationally protected plants, making up 11.64% of the total. Of these, 15 are in Heilongjiang Province, 13 in Jilin Province and four in Liaoning Province. Thirty-five counties (cities, districts) have between 6 and 10 species of nationally protected plants, accounting for 12.73% of the total. Amongst these, 19 are in Heilongjiang Province, six in Jilin Province and 10 in Liaoning Province. The vast majority of counties (cities, districts) have 1 - 5 species of nationally protected plants, accounting for 64% of the total counties (cities, districts) (Fig. 18).

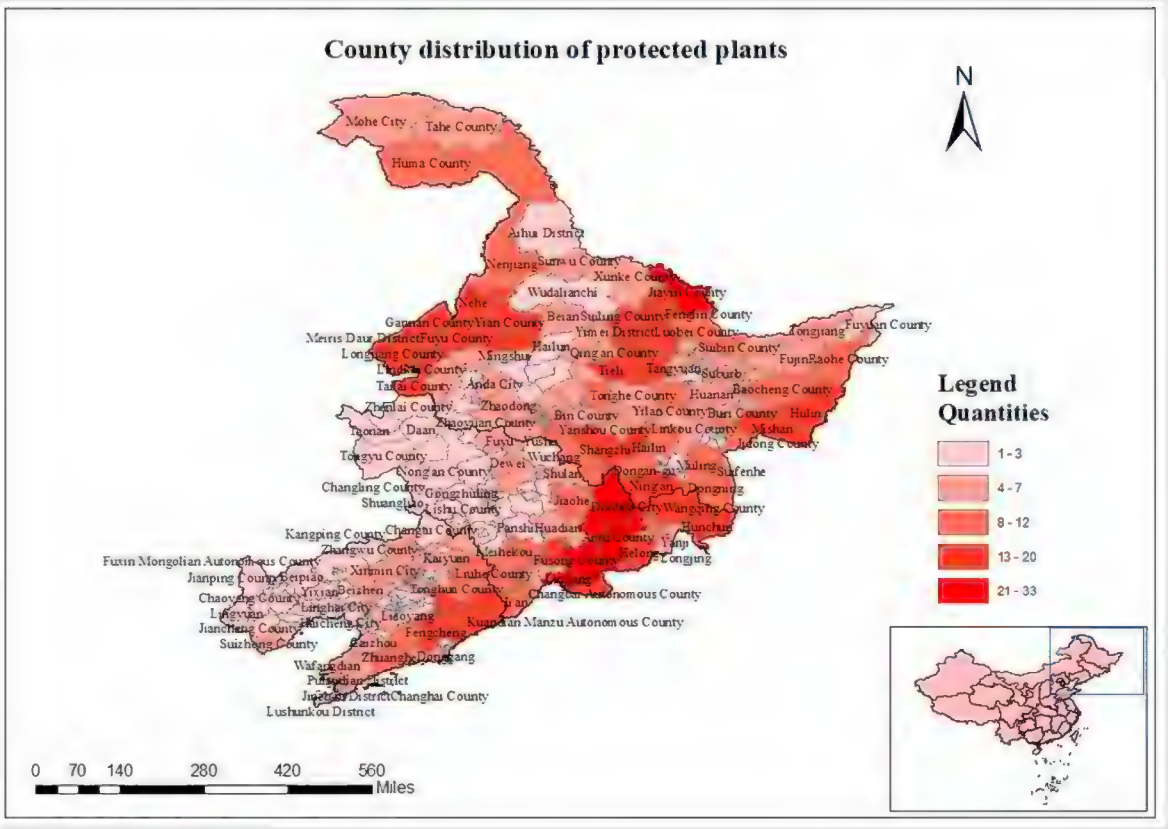

Figure 18. doi

The number of species of nationally protected key plants at the county level in the three most north-eastern provinces.

Distribution by geographical units

The three most north-eastern provinces of China (Heilongjiang, Jilin and Liaoning) can be divided into several geographical regions: the Greater Khingan Range, the Lesser Khingan Range, the Changbai Mountains, the Northeast Plain and the Liaodong Peninsula (Fig. 19). The Greater Khingan Range is home to nine families, 10 genera and 13 species of protected plants. The Lesser Khingan Range is home to 12 families, 14 genera and 20 species of protected plants.The Changbai Mountains consist of a series of parallel northeast-southwest mountain ranges and several northwest- and east-west-orientated mountain ranges. The major mountains include the Zhangguangcai Ridge, Xialaoye Ridge, Jilin Hadaling, Weihuling, Longgang Mountain, Laoling, Mudan Ridge, Ying'e Ridge, Zengfeng Ridge, Nangang Mountain, Harbaling, Laosong Ridge, Mulingwoji Ridge, Panling and Dalong Ridge. The Changbai Mountains host 26 families, 29 genera and 39 species of protected plants. Amongst these, the Zhangguangcai Ridge has the highest number of protected plant species, with 23 families, 27 genera and 34 species. The Mudan Ridge and Harbaling both have 20 families, 24 genera and 30 species. Laoling has 18 families, 21 genera and 29 species.The Northeast Plain is composed of the Songnen Plain, the Sanjiang Plain and the Liaohe Plain. The Songnen Plain hosts 22 families, 24 genera and 30 species of protected plants. The Sanjiang Plain is home to 15 families, 16 genera and 21 species. The Liaohe Plain has 12 families, 14 genera and 14 species of protected plants. The Liaodong Peninsula, located in the south-eastern part of Liaoning Province, has 16 families, 20 genera and 22 species of protected plants.

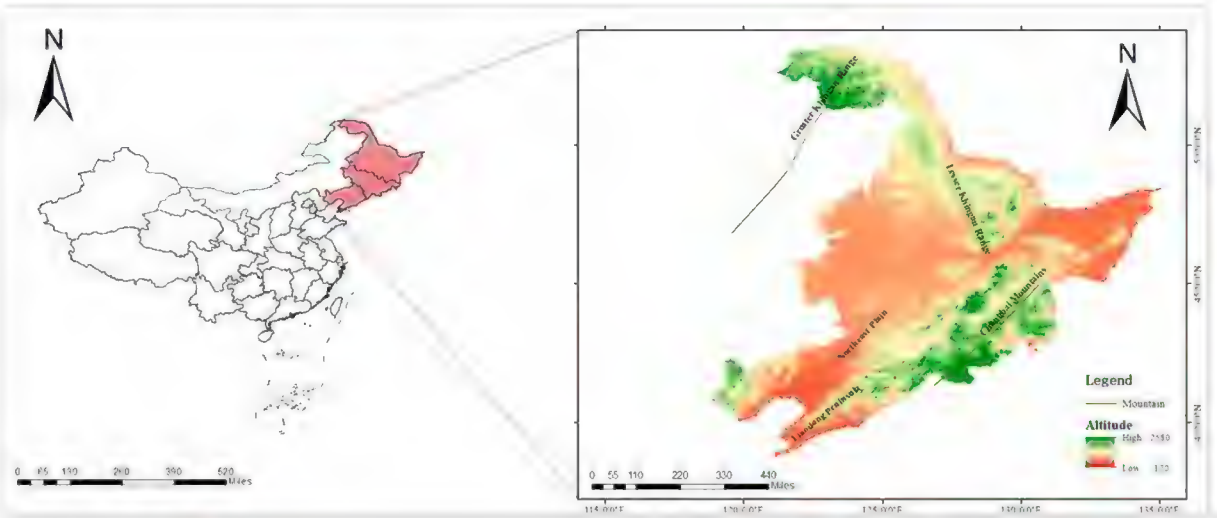

Figure 19. doi

The terrain and mountain ranges in the three most north-eastern provinces.

The region can be divided into four river basins: the Heilong River (Amur River), the Liao River, the Yalu River and the Tumen River (Fig. 20).The Heilong River is divided into three tiers of tributaries. The first-tier tributaries flowing through the three most north-eastern provinces are Beijicun River, Emuer River, Pangu River, Xiergenqi River, Huma River, Kuan River, Tuoniu River, Fabila River, Cierbin River, Shijin River, Gongbiela River, Xun River, Kuerbin River, Wuyun River, Jielie River, Ulagu River, Jiayin River, Yadan River, Lianhua River, Qinglong River, Yalu River, Nongjiang River, Songhua

River, Ussuri River and Hutong River. The second-tier tributaries flowing through the three provinces include the Emuer River tributary, Huma River tributary, Xun River tributary, Kuerbin River tributary, Songhua River tributary and Ussuri River tributary. The third-tier direct tributaries include Hama River, Songmu River, Yichun River and Qixing River. Amongst these, the Songhua River is the largest first-tier tributary of the Heilong River, with its tributaries including the Nen River, Majiagou River, Mudan River and Hulan River, hosting 18 families, 21 genera and 27 species of protected plants. The Ussuri River is the second-largest, with tributaries such as Songacha River, Xiaomuling River, Muling River and Qihulin River, hosting 13 families, 13 genera and 15 species of protected plants.The Liao River flowing through the three most north-eastern provinces has major tributaries including the West Liao River, East Liao River, Xiushui River, Raoyang River, Zhaosutai River, Yangximu River and Chai River, with 10 families, 12 genera and 12 species of protected plants.The Yalu River, which also flows through the three most north-eastern provinces, has major tributaries such as the Hun River, Pushi River and the Yuan River, hosting 15 families, 17 genera and 23 species of protected plants.The Tumen River flows from south to north through four counties and cities in China: Helong, Longjing, Tumen and Hunchun. Its main tributaries are located within these counties and cities, with 12 families, 13 genera and 15 species of protected plants.

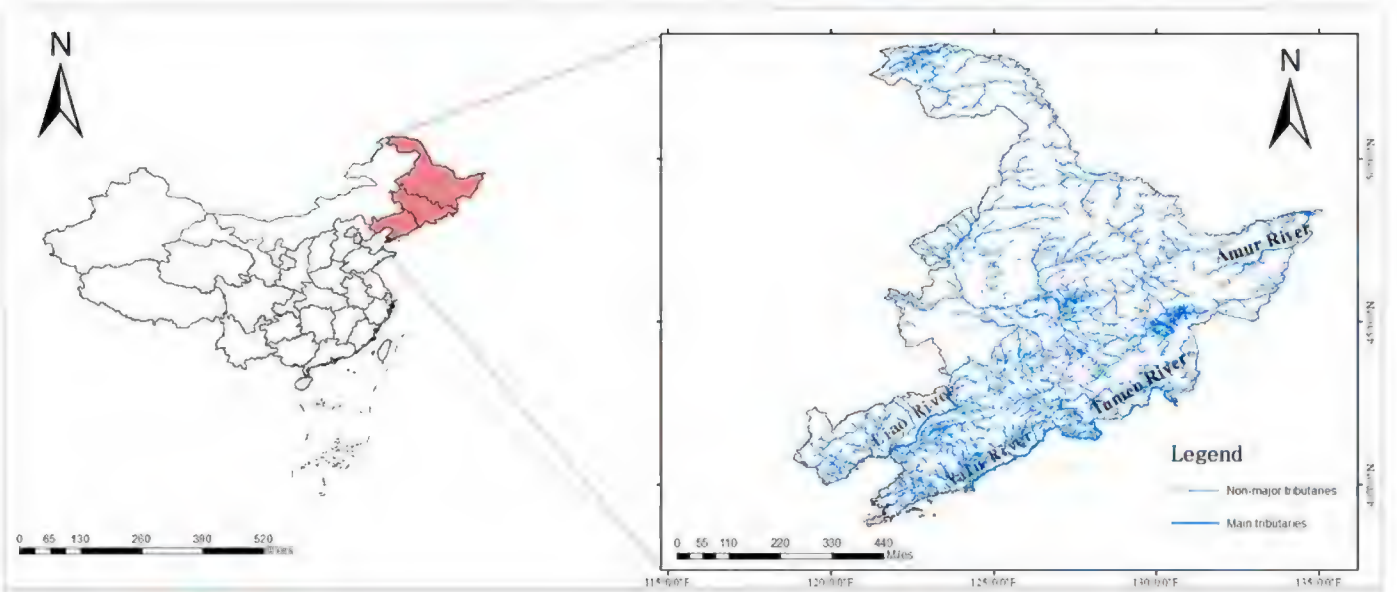

Figure 20. doi

River map of the three most north-eastern provinces.

Threat level

According to the *China Biodiversity Red List – Higher Plants Volume (2020)*, amongst the nationally protected plants in the three most north-eastern provinces, there are two species with insufficient data (DD), eight species classified as Least Concern (LC), three species classified as Near Threatened (NT), thirteen species classified as Vulnerable (VU), nine species classified as Endangered (EN) and three species classified as Critically Endangered (CR). The species classified as Vulnerable (VU), Endangered (EN) and Critically Endangered (CR) are collectively referred to as "threatened species". There are 25 threatened species in total, accounting for 65.79% of the total number (Fig. 21).

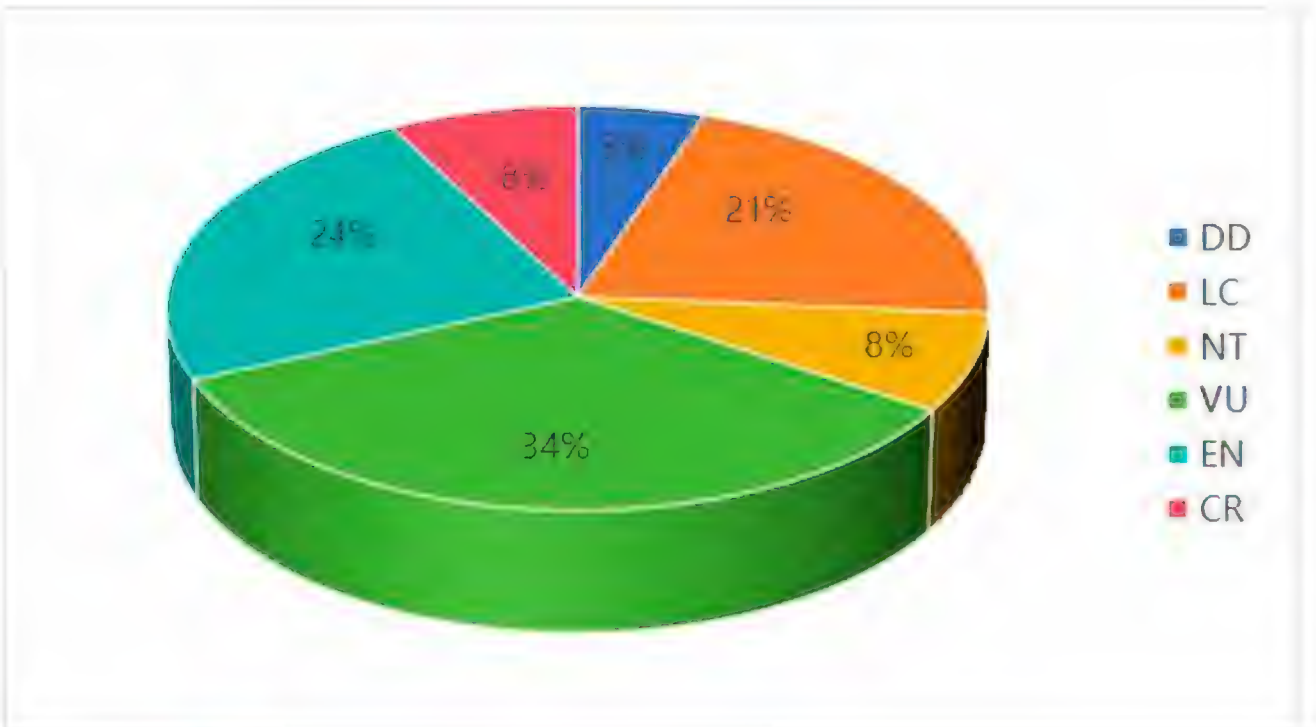

Figure 21. doi

Threat level of national key protected plants in the three most north-eastern provinces in China.

According to the International Union for Conservation of Nature (IUCN 2002), there are 19 nationally protected plants in the three most north-eastern provinces that have been assessed and have sufficient data. Amongst these, 14 species are classified as Least Concern (LC), one species is classified as Near Threatened (NT), two species are classified as Vulnerable (VU) and two species are classified as Endangered (EN) (Fig. 22).

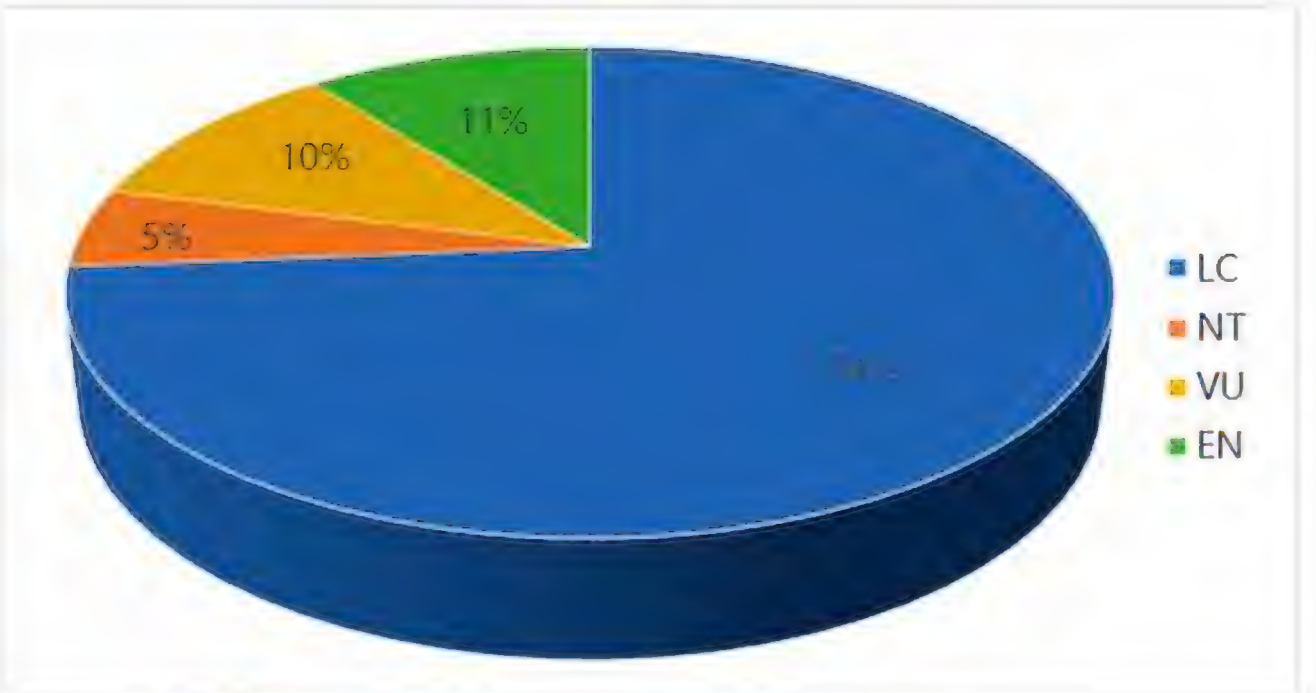

Figure 22. doi

Global threat level level of national key protected plants in the three most north-eastern provinces.

Threat factors

According to the standards of the International Union for Conservation of Nature (IUCN), the factors that lead to the loss of biodiversity are categorised into 12 types: (1) Residential & commercial development; (2) Agriculture & aquaculture; (3) Energy production & mining; (4) Transportation & service corridors; (5) Biological resources use; (6) Human intrusions & disturbance; (7) Natural system modifications; (8) Invasive and other problematic species, genes & diseases; (9) Pollution; (10) Geological events; (11) Climate change & severe weather; (12) Other factors. Amongst these, 10 threats affect the key protected plant species in the north-eastern provinces of China, namely: Residential & commercial development; Agriculture & aquaculture; Energy production & mining; Transportation & service corridors; Biological resources use; Human intrusions & disturbance; Natural system modifications; Invasive and other problematic species, genes & diseases; Pollution; Climate change & severe weather. There are seven plants with unknown threat factors, including *Brasenia schreberi*, *Trapa incisa*, *Myriophyllum ussuriense*, *Coleanthus subtilis*, *Sparganium hyperboreum*, *Gastrodia elata* and *Scheuchzeria palustris* (Table 1).

Table 1.

Threat levels and threat factors of plants under state priority protection in the most north-eastern provinces of China.

Scientific name	Threat level	Threat factors
Aldrovanda vesiculosa	Endangered	Residential & commercial development; Agriculture & aquaculture; Energy production & mining; Biological resource use; Natural system modifications; Pollution.
Brasenia schreberi	Least Concern	Uncharted
Coleanthus subtilis	Least Concern	Uncharted
Cypripedium calceolus	Least Concern	Residential & commercial development; Agriculture & aquaculture; Biological resource use; Natural system modifications; Pollution.
Cypripedium guttatum	Least Concern	Residential & commericial development; Transportation & disturbance; Natural system modifications; Climate change & severe weather.
Cypripedium macranthos	Least Concern	Residential & commercial development; Agriculture & aquaculture; Transportation & service corridors; Biological resource use; Human intrusions & disturbance; Natural system modifications; Invasive and other problematic species.
Cypripedium shanxiense	Near Threatened	Residential & commercial development; Agriculture & aquaculture; Transportation & service corridors; Biological resource use; Human intrusions & disturbance; Pollution; Climate change & severe weather.

Scientific name	Threat level	Threat factors
Fraxinus mandshurica	Least Concern	Residential & commercial development; Agriculture & aquaculture; Biological resource use; Climate change & severe weather.
Gastrodia elata	Vulnerable	Uncharted
Malus komarovii	Endangered	Residential & commercial development; Transportation & service corridors; Biological resource use; Human intrusions & disturbance; Natural system modifications; Pollution; Climate change & severe weather.
Myriophyllum ussuriense	Least Concern	Uncharted
Ottelia alismoides	Least Concern	Biological resource use; Human intrustions & disturbance; Pollution.
Pinus koraiensis	Least Concern	Biological resource use; Invasive and other problematic species.
Scheuchzeria palustris	Least Concern	Uncharted
Sparganium hyperboreum	Least Concern	Uncharted
Taxus cuspidata	Least Concern	Biological resource use.
Thuja koraiensis	Vulnerable	Biological resource use; Human intrusions & disturbance.
Tilia amurensis	Least Concern	Residential & commercial development; Agriculture & aquaculture; Biological resource use.
Trapa incisa	Least Concern	Uncharted

Current status of research

Amongst the 51 nationally protected plants, the more researched species were mostly those with economic value, such as *Pinus koraiensis*, *Tricholoma matsutake*, *Actinidia arguta*, *Nelumbo nucifera*, *Glycine soja* and *Panax ginseng*. There are seven species that are basically not covered by research, including *Cypripedium calceolus*, *Cypripedium* × *ventricosum*, *Huperzia miyoshiana*, *Huperzia selago*, *Huperzia asiatica*, *Sparganium hyperboreum* and *Myriophyllum ussuriense*, five of which are in the new version of the List of Wild Plants under State Key Conservation (2021) (National Forestry and Grassland Administration 2021) and the current status of the resources of *Sparganium hyperboreum* and *Myriophyllum ussuriense* are still not clear.

Most of the nationally protected plants in the three most north-eastern provinces of China have medicinal, edible, industrial and ornamental values. Amongst them, *Aldrovanda vesiculosa* can be used as an environmental indicator plant and its presence signals that

the ecological environment of the watershed is excellent (Shan et al. 2020). In addition to its edible and ornamental values, *Malus komarovii* can be widely used as an excellent rootstock for breeding new cold-resistant dwarf varieties of the genus *Malus* (Wang et al. 2022). *Thuja koraiensis* has important academic research value for exploring the ancient flora and cypress family classification and phylogeny (Yuan et al. 2022).

Most plants reproduce in two ways, sexual and asexual. Sexual reproduction is mainly through seeds and asexual reproduction is mainly through nutrient organs. *Boschniakia rossica* is a highly-specialised parasitic plant that only parasitises the roots of *Alnus mandshurica* or *Alnus hirsuta* of the genus *Alnus* in the family Betulaceae and requires seeds to be able to access the host root tip in order to reproduce (Chen et al. 2015). Some scholars have found that *Cypripedium macranthos* is in highly-specialised symbiosis with Epulorhiza, which has an obvious promotion effect on *Cypripedium macranthos* seed germination. It has been shown that the most effective propagation method for non-symbiotic germination of *Cypripedium macranthos* is isolated seed germination, which is also a commonly used method of artificial propagation in orchids. It has been found that *Cypripedium macranthos* can also rely on other mycorrhizal fungi for the nutrients needed for seed germination and growth (Fan et al. 2023). It is now understood that *Armillaria mellea* is a symbiotic species of *Gastrodia elata*, which can only grow if *Armillaria mellea* provides it with nutrients and the two are interdependent. Research has shown that the more vigorous growth of *Armillaria mellea*, the more nutrition for *Gastrodia elata*, the more rapid growth. *Gastrodia elata* seedling reproduction methods are divided into sexual reproduction and asexual reproduction of two kinds. Sexual reproduction is propagation with *Gastrodia elata* seeds, which requires seeds, germinating bacteria and *Armillaria mellea*; asexual propagation takes nutrient organs, i.e. rice or white flax as propagation materials, which requires rice or white flax and *Armillaria mellea* (*Wang 2023, You 2023*).

According to the literature examined, it is known that in-situ protection has been adopted for *Thuja koraiensis* and a nature reserve for *Thuja koraiensis* has been established in Changbai Mountain, China (Zhou et al. 2023). It has been analysed and found that more than half of the Orchidaceae in China have been protected in situ to varying degrees in protected areas (Li 2020). It is now understood that in-situ conservation is one of the most important measures to address the conservation, restoration and reconstruction of *Lilium amabile* populations (Cui 2023).

A total of 51 species of national key protected wild plants, belonging to 38 genera and 31 families, are found in the three north-eastern provinces of China. Of these, 72.55% are distributed within 77 national nature reserves in the region, primarily concentrated in the Changbai Mountain National Nature Reserve, Liangshui National Nature Reserve and Bailang Mountain National Nature Reserve. The majority of these protected plants are conserved in situ. However, 14 species have not been found within any national nature reserves, including *Scheuchzeria palustris*, *Zoysia sinica*, *Coleanthus subtilis*, *Rhodiola sachalinensis*, *Cypripedium shanxiense*, *Silvetia siliquosa*, *Sphagnum multifibrosum*, *Trapa incisa*, *Glehnia littoralis*, *Huperzia miyoshiana*, *Huperzia selago*, *Huperzia serrata*, *Huperzia asiatica* and *Ottelia alismoides*. Amongst them, *Scheuchzeria palustris*,

Sphagnum multifibrosum, *Huperzia miyoshiana*, *Huperzia selago* and *Huperzia asiatica* are data deficient, indicating significant research gaps.Research has been conducted on the geographical distribution and endangered status of *Coleanthus subtilis* both in China and globally (Liu et al. 2022); on seedling collection and propagation techniques, active ingredient extraction and fibre preparation of *Silvetia siliquosa* (Huang et al. 2008, Kui et al. 2023); on the geographical distribution patterns, morphological diversity, physicochemical properties and chromosome-level genome of *Trapa incisa* (Guan et al. 2009, Xue et al. 2016, Qu et al. 2023); on the new geographical distribution, endophytic fungal species, seed morphology and germination characteristics of *Cypripedium shanxiense* (Gu et al. 2018, Li and Li 2020, Zhou et al. 2024); on photosynthesis, carbon concentration mechanisms, fruit and seed developmental morphology of *Ottelia alismoides* (*Fu et al. 2018*); on chemical composition, cultivation techniques and field re-introduction of *Rhodiola sachalinensis* (Liu et al. 2015, Jia 2022); on physiological and biochemical characteristics, reproduction techniques, applications and habitat protection of *Zoysia sinica* (Du et al. 2007, Ma 2011, Zhang 2014); on physiological and biochemical properties, chemical composition, application value, genetic diversity, anatomy, breeding systems and embryology of *Glehnia littoralis* (Yang et al. 2023, Zhou 2023, An et al. 2024); and on physiological and biochemical properties, habitat suitability prediction, reproduction, value, cultivation techniques, population structure and threat factors of *Huperzia serrata* (Ma et al. 2016, Qi and Wang 2017, Chen et al. 2022, Chen and Yu 2023, Pang 2023). While research progress on these plants has been made in certain areas, there are still significant research gaps.

Discussion

Distribution pattern

The distribution of national key protected plants in the three most north-eastern provinces shows obvious regional differences. Heilongjiang Province has the largest number of protected plant species and dominates the area, which may be related to its extensive forest cover and diverse ecosystems (Dong et al. 1988). Although Jilin Province is smaller in size, it has a more concentrated distribution of protected plants, especially in the Changbai Mountain area, reflecting the importance of the region in ecological conservation (Jilin Provincial Department of Ecology and Environment 2024). Liaoning Province has a relatively low distribution of protected plants, which may be related to its higher level of urbanisation and intensity of human activities (Lu et al. 2022). The Changbai Mountain Range is the region with the most concentrated distribution of protected plants in the three north-eastern provinces, especially Zhangguangcailing, Mudanling and Harbaling, reflecting the importance of this region in biodiversity conservation (Duan et al. 2019). Daxing'anling is the northernmost mountain range in China, with a cold climate and vegetation dominated by cold-temperate coniferous forests, with relatively few protected plant species, but with unique ecological value (Shu et al. 2024). The greater number of protected plant species in the Xiaoxinganling reflects the complexity and stability of its ecosystem (Liu 2012). The distribution of protected

plants in the Northeast Plain is greatly affected by agricultural development and urbanisation, especially in the Liaohe Plain, where there are fewer protected plant species (Liu et al. 2024). The Liaodong Peninsula has more protected plant species, but the urbanisation process may pose a threat to its ecosystem (Xu 2024). The Songhua River Basin is the area with the most concentrated distribution of protected plants, reflecting its importance in the ecosystems of the three north-eastern provinces (PRC Ministry of Ecology and Environment et al. 2018). The Yalu River Basin has a large number of protected plant species, reflecting the complexity and stability of its ecosystem (Cao et al. 2006). The Liao River Basin has a low distribution of protected plants, which may be related to the high level of agricultural development and urbanisation in the Basin (Li et al. 2022). The distribution of protected plants in the Tumen River Basin is more uniform, but with fewer species, which may be related to the smaller size of the Basin and the intensity of human activities (Wang et al. 2002). In summary, the distribution of protected plants in the three most north-eastern provinces is influenced by a variety of factors, including geography, climate, ecosystem type and human activities.

Endangered status and research status

The results of these assessments reflect the current conservation status and the level of threat faced by plants under State Key Conservation in the three north-eastern provinces. The threat factors for some plants are not yet clear, including *Brasenia schreberi*, *Trapa incisa*, *Myriophyllum ussuriense*, *Ottelia alismoides*, *Coleanthus subtilis*, *Sparganium hyperboreum*, *Gastrodia elata* and *Scheuchzeria palustris*. Therefore, in-depth ecological studies on these plants are urgently needed to clarify the specific threat factors they face and to provide a scientific basis for formulating effective conservation measures.

Progress has been made in scientific research and conservation of national key protected plants in the three north-eastern provinces, but some research gaps and conservation challenges remain. For example, the *Cypripedium shanxiense*, as a national key wild plant under Grade II protection, is listed as a vulnerable species (VU) in the Red List of Chinese Species and in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and its trade needs to be strictly regulated in order to avoid impacts on its survival (Import and Export Administration Office of the People's Republic of China for Endangered Species and Scientific Committee on Endangered Species of the People's Republic of China 2010). However, some of the plants are still understudied and the current status of the resources is unknown. For example, relatively little research has been done on plants such as *Huperzia miyoshiana*, *Huperzia selago*, *Huperzia lucidula*, *Myriophyllum ussuriense* and *Sparganium hyperboreum*. Amongst them, although the *Myriophyllum ussuriense* and *Sparganium hyperboreum* are listed in the new version of the List of Wild Plants under State Key Protection in 2021, the status of their resources is still not fully clarified. Orchidaceae have important scientific research value due to their unique morphological features and ecological habits. However, rampant illegal collection and trade, coupled with their demanding habitat requirements, have led to a serious endangerment of their wild resources. The 2021's newly-adjusted List of Wild Plants under State Key Protection

included 349 species of Orchidaceae from 23 genera and more than 1,000 species of Orchidaceae are now located in national nature reserves. Conservation measures for Orchidaceae include mapping the resource base, carrying out science popularisation and education and strengthening artificial breeding and cultivation (Zhang et al. 2022).

Overall, research on plants under national key protection in the three most north-eastern provinces has achieved certain results and relevant monographs, such as the Atlas of Plant Distribution in Northeast China (Cao 2019a), Atlas of the Primary Colours of Forest Plants in Northeast China (Cao 2019b) and Atlas of Major Forest Plants and Their Anatomy in Northeast China (Wang et al. 2018), have provided important references for plant research. However, there are still some plants that lack systematic research and conservation measures, which urgently need more attention. In the future, we should further deepen the research on plants under national key protection and improve conservation strategies to ensure their survival and reproduction.

Limitations and future research

This study mainly collects information on plants under national priority protection through online databases, literature and some field survey data. Although a large amount of relevant data is covered, there are still problems of incomplete or untimely updating of data.

Firstly, limitations in data sources may affect the accuracy of the study results. Some of the studies relied on historical documents or fragmented data records and, although they combined field surveys, they were limited in scope and failed to cover the distribution areas of all protected plants due to time and resource constraints, resulting in insufficiently current and comprehensive data. In addition, the resource status of certain plants is still unclear, such as *Myriophyllum ussuriense* and *Sparganium hyperboreum*, which are included in the list of national key wild plants for protection, but lack detailed data on the current status of the resources and systematic assessment of the threatened factors.

Secondly, the endangered status has dynamic changes and uncertainty. This study categorises the threat factors of plants under national key protection in the three most north-eastern provinces, based on IUCN standards, but these threat factors may change over time due to environmental changes and human activities. For example, climate change, land-use change and increased human disturbance may further deteriorate the survival of certain species or their threat level may decrease after effective conservation measures are taken. Continuous monitoring and dynamic assessment are therefore essential.

In addition, there are limitations and research gaps in the data on conservation measures. This paper mainly counted in-situ conservation, focusing on the distribution of protected plants in national nature reserves. However, the three key conservation measures of relocation protection, field return and isolated conservation were not addressed, resulting in certain data gaps in conservation measures. For example, many

rare and endangered plants have been relocated and bred in botanical gardens, scientific research institutes or specialised conservation bases, but there are fewer systematic assessments of their growth status, survival rate and reproductive capacity in relocated environments. In addition, there is still a lack of relevant experimental data on key protected plants in the three most north-eastern provinces for field return as an important measure to restore populations of endangered species. In-vitro conservation techniques, such as seed banking, tissue culture and cryopreservation, are essential for the long-term conservation of genetic resources, but there are fewer studies on their application to protected plants in the three most north-eastern provinces.

Based on the above limitations, future research should be carried out in the following aspects: (1) Strengthening data collection and updating: using modern scientific and technological means such as remote sensing technology, GIS spatial analysis and drone monitoring, combined with data from long-term field surveys, systematic surveys of protected plant resources, especially for species with a lack of data and long-term ecological monitoring and resource surveys should be carried out in order to fill in the gaps in research. At the same time, the monitoring and survey data will be integrated into a database and updated and shared in a timely manner; (2) Evaluation and monitoring of endangered status: For the national key protected plants in different areas of the three north-eastern provinces, carry out evaluation of climate change, habitat destruction, human interference and other influencing factors and establish a long-term monitoring mechanism; (3) Strengthening research on conservation measures: Investigations on relocation breeding in botanical gardens, scientific research institutes or specialised conservation bases should be strengthened and technical research on relocation conservation and isolated conservation should be enhanced for plants under national key protection outside nature reserves, as well as exploring suitable strategies for return to the wild to improve the ability of populations to survive.

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